Cultural and Environmental Factors Affecting the Production of *Dendranthema x grandiflorum*

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by

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Abstract

The purpose of this experiment was to reduce the schedule of cut mum production by decreasing the number weeks of long days and supplementing the flowers with the plant hormone gibberellic acid (GA). GA is a plant hormone which enlarges the cells of the stems and could conceivably affect mum vegetative growth during long days. In this experiment, long days were reduced to 0, 3, 10, 13, 17 and 20. During the long day treatments, different rates of products were applied. Both ProGibb 4% and Fascination were used to look at the effects of the different variations of GA; GA_3, GA_4, and GA_7.

Table of Contents

List of Tables

List of Figures

Introduction

Greenhouse production is expensive. Heating, lighting, labor, materials all cost a lot of money. But the initial costs are worth it so long as the customers are willing to pay for it. But now with overseas competition, they are producing the same product at a lower cost. Customers can get the same product at a lower cost if they buy imported products.

In order for US growers to compete they need to be as efficient as possible. One way of doing this is to increase their production by shortening the schedule of their crop in order to have more rotations of that crop on the same plot of land throughout the year. There are many ways to shorten the schedule of a crop, but often times the end product is not acceptable. The hypothesis is that GA can be applied to a mum crop during long days to increase the height of the stems so they can be put into short days earlier, thus reducing the total crop time.

GA was first registered in 1947 as a growth regulator in the US. It was initially used to control russet fungus in apples. GAs are naturally occuring plant hormones which encourage cell division and elongation (Anonymous, EPA R.E.D. FACTS).

The name *Chrysanthemum* means "golden flower" as derived from Greek. It is in the Asteraceae family. They are annuals and sometimes grown as perennials (Anonymous, Understanding and Producing Chrysanthemums).

Cut mums are generally marketed as one inflorescence per shoot, either standard or disbud. Cut mums can be grown on a year round basis. Long stems are required for cut flowers. A longer production time is needed if the cut mums get pinched for additional growth. Mums are not necessarily associated with any particular holiday, so they can be grown on a year round basis.

Most production has shifted to areas of higher light intensities and more economical labor, such as in off-shore competition. If domestic growers want to compete, then they will have to reduce their costs. There are thousands of cultivars on the commercial market. As production has shifted around the world, may cultivars have not been grown because they were too fragile or difficult to transport, such as spiders and large single daisies (Emeritus and Wilkens, 432-33).

The objective is to increase United States production of cut mums by shortening the schedule of their crop in order to have more rotations of that crop on the same plot of land. Gibberellic acid can be applied to a mum crop just after their rooted cuttings have been established in order to increase the height of the stems so they can be put into short days earlier.

Literature Review

Provenance and Attributes

Chrysanthemums, *Dendranthema x grandiflorum* or *Chrysanthemum morifolium*, are herbaceous annuals and sometimes perennials from the family Asteraceae (Emeritus et. al., 432-33). They are native to China and were bred there and in Japan for 2,000 years until it finally became available in Europe in the 1800s (Kessler and Raybond).The ancestor of this plant is *Dendranthema indicum* (L.) Desmoul (Floriculture book 432-433). Just 70 years ago, the interest of mums shifted to production pot crops. Mums have been bred to be white, yellow, red, bronze, pink and bicolors. There can also be classified by flower shape which includes singles, quilled, anemones, spider, pompons, decoratives and large flowered. These flower forms can have different petal shapes including spoons, quill, and flat. Further classification includes cultural types such as standards, disbuds and sprays. Finally they can by grouped by height and response group (Kessler and Raybond). Tall varieties flower on stems longer than 15inches after the start of short days, medium varieties flower at 15inches, and short varieties are just under 15inches (Emeritus and Wilkens, 432-33).

Value in the Cut Flower Industry

Chrysanthems can be grown as cut flowers, potted plants, and for gardens. (Anonymous, Understanding and Producing Chrysanthemums). Over the last 30 years the popularity of mums has grown tremendously as well as has the commercial industry. About 200,000 hectares of land are used for the production of cut flowers, and chrysanthemums are one of the top three being produced (Dolan and Opondo).

Challenges and problems in production systems

One of the biggest problems with flower production is the cost. Within the last two decades Columbia has become the number two exporter of cut flowers in the world, just behind the Netherlands, which supplies just under 10% of the cut flowers to the world. This is due to the increased technology in transportation by air and post-harvest technology. Mums typically last 7-14 days, depending on the variety, and now with air shipments it is possible to grow the crop overseas and sell it within the US. This technology opened up the world to a global market. So, as air transportation became easier, so did importing flowers. Columbia has risen to the second largest importer in the world because they have cheap labor, good weather and cheap land, therefore making production more favorable overseas. The prices were lower for the consumer and there were new varieties and more availability. While the cut flower industry has improved in terms of efficiency, it has also hurt the US producers (Mendez).

There are also some growing problems which can affect schedule, and that has to do with juvenility. Juvenility can occur with cuttings if they are taken from younger stock plants as opposed to mature stock. The cuttings from older stock are physiologically older and will become reproductive more quickly. Another common problem is crown buds. If the stock are left under long days and cuttings are taken from them, they will form a crown bud, which is a terminal bud which is reproductive but likely won't flower. It is important for the propagators to get new stock quarter annually and to not take cuttings from old shoots (Emeritus and Wilkens, 435).

Chrysanthemum Cultural Information

Mums have specific growing information which should be followed in order to have the most success. To start off, it is critical to have pathogen free rootstock and cuttings. Terminal cuttings

can be sold as rooted or un-rooted and should be at least 2 ½ - 3 inches long. The un-rooted cuttings will root within 1-2 weeks. A rooting hormone may be used, but is not necessary. The cuttings should be kept under long days in order to maintain vegetative growth. When planting, stick the cuttings at a 45 degree angle, in order to make the final plant fuller. For pinched cut flowers, space the rooted cuttings 6 x 7 inches in summer and 7 x 8x 9 inches in winter. For non-pinched plants use 4 x 6 for summer and 5 x 6 for winter for maximum lighting. Typically, use at least 200 ppm N in constant liquid fertilizer once established. Media should be between 5.7-6.2 pH (Emeritus and Wilkens, 435, 438).

When watering, the roots of mums must be well drained. Drip irrigation is most common for ground beds. It is also important to not let the salts accumulate. CO_2 can be important for enhancing the growth and quality of cut mums. CO_2 is more effective with supplemental light with HID. CO_2 is only used during the day. Flower number will increase with 900 ppm. Typically, 1000 ppm is used commercially and is started 1 hour before sunrise until 1 hour before dark. With this routine, the mums will flower 1 week earlier and will be stronger and bigger (Emeritus and Wilkens, 437).

Flowering Process

There are some important concepts to understand regarding the flowering process in order to effectively grow mums. The first stage of flowering is called induction and it is when the chemical processes of flowering begin. Flower initiation is when, under a microscope, the first signs of the flower are visible. This includes the floral organs and when the apical meristem has changed shape. Then the flower goes through development. This portion can easily be affected by the environment. Inadequate vernalization can cause abortions. Anthesis is the first signs of

pollen showing and is considered flowering. The final stage is the wilting and abscission of the flower which often leads to fruiting and is called senescence (Emeritus and Wilkens, 36).

Scheduling

A schedule is created for every crop grown and is often done ahead of time for the entire year. The schedule is determined by the finishing date which is when the crop is harvested and sold. Knowing the time it takes to grow a certain commodity is very important as well as knowing the other factors which can lengthen or shorten the growing process. Examples include the variety, the desired height, the propagation time and the flower form. Latitudes, climates, season, and location are also influences (Emeritus and Wilkens, 441).

Stick the cutting under long days (LD) and allow 1-2 weeks for the un-rooted cutting to root. If the cutting is already rooted then no additional time is required. Keep the established cuttings under LD, allow them to grow for an addition 1-3 weeks to allow for vegetative growth and height. Pinch the plants and then start short days (SD). Depending on the cultivar and the desired height, it may take 6-15 weeks to flower. The entire growing process may take between 8-17 weeks (Kessler and Raybond). The week system is the simplest way to create a schedule. For example the first week of January is week1 and the last week of December is week 52 (Emeritus and Wilkens, 37).

Response Groups

Mums can be classified by their response groups. Response groups are important for creating a schedule and determining a correct finishing date. Response groups of mums are classified by the amount of time required to flower from the start of short days. This part of the growing process typically takes 6-15 weeks and is determined by the variety of the commodity. Response groups are shorter when there is a shorter critical night length needed for floral

initiation of the plant, which requires a longer critical photoperiod. This is the opposite of a longer response groups that need longer critical nights, which is a shorter critical photoperiod. (Emeritus and Wilkens, 435-36).

Photoperiodism

Photoperiodism is a night length response. It controls flower bud initiation and flower bud development, dormancy, germination, development of storage organs and growth in mums and in many other photoperiodic plants. Short day plants will flower when the hours of dark are longer than the critical day length. Long day plants are the opposite of short day plants. There are also day neutral plants. Facultative plants can flower under different day lengths but is most effective when under either SD or LD. When the number of day/ night cycles increases, the time to anthesis decreases. There are also obligate plants which have more specific photoperiods (Emeritus and Wilkens, 37).

Chrysanthemums are obligate short day plants and are affected by photoperiodism. They are vegetative when the day length is longer than the critical day length. They flower when day length is shorter than critical day length. They flower in the fall naturally when day lengths are shorter. But, they can be grown out of season when black clothing and supplemental lighting is used. Mums have a floral initiation critical photoperiod and also a development critical photoperiod. The response groups of cut mums can be anywhere between 6 and 15 weeks. Floral initiation critical day length is between 16 and 11 hours. The flower development critical day length is between 13 and 10 hours (Emeritus and Wilkens, 37).

There are other factors which may affect photoperiod, such as temperature. Flower induction and development for chrysanthemums can be delayed by night temperatures if they are over 85 degrees F. When night temperatures increase from 64-75 degrees F, shorter photoperiods

are needed to reduce the time to flowering. 8 to 12 hour days are needed at temperatures of 64 degrees F and 8-10 hours are needed if at 75 degrees F. Light intensity can also have effects on initiation and development (Emeritus and Wilkens, 36-7).

Mums, and other photoperiodic plants, contain phytochrome, which is a pigment that has two forms and can interchange between these forms depending on the quality of light. One form absorbs far red light and the other absorbs red light. Flower initiation is inhibited by far red light and is the active in the dominant form (Anonymous, Understanding and Producing Chrysanthemums).

Mums flower naturally in the fall or winter when the day lengths are shorter. Commercially, but they are grown year round. The critical photoperiod for reproductive growth is 12 hours or less. It is 14 hours or more for vegetative growth. With 14 hours or less, floral induction can occur but flower development cannot continue (Emeritus and Wilkens, 435).

SD plants flower more rapidly under short days, which can be accomplished commercially by using black cloth which can be pulled on at 1700 hours and removed at 0700 hours. In the Northern hemisphere this is often done between March 15th and September 15th. Long day plants can use incandescent lights for night lighting. As light intensity and saturation increase, reproductive growth stops. Continuous lighting is done at 7-10 foot candles. Night lighting can also occur as cyclic lighting, which can be used as 6 minutes on, then 24 hours off for 4 hours with a minimum of 10 foot candles at the apex of the shoot. High-intensity discharge (HID) lighting can also be used (Emeritus and Wilkens, 436).

Floral development is very specific for mum flowers. At any one time, 13 leaf primordia are within a vegetative meristem. 7-9 days after the start of short days, microscopic reproductive changes occur. After 24-30 days, flower bud initiation is complete. Once terminal bud petals

start to show color, plants can be removed from SD to LD. Temperature affects flower bud initiation and development and can be delayed if they don't receive the correct temperatures during SD (Emeritus and Wilkens, 436). Delays occur if temperatures reach above 85 degrees F during the early part of the SDs which is referred to as heat delay. If the black cloth is removed in the evenings when the temperatures are lower and opened in the middle of the night then heat can be release and the heat delay can be prevented. High humidity can also delay flowering and the flower dry weight will be reduced due to reduced transpiration (Emeritus and Wilkens, 437).

Plant Growth Regulators Effectiveness

A plant growth regulator is defined as a growth response triggered by a chemical process. Examples include elongation or inhibition of stem growth. Naturally occurring endogenous hormone levels get manipulated. This effect is often achieved through exogenous spray applications or endogenous drench applications. Gibberellic acid (GA) is used commercially for many different plants to elongated stems, enhance flower development and seed germination. The most frequent used forms are GA_3, GA_4 and GA_7 (Emeritus and Wilkens, 142). It has been noted that elongating stems by using GA can result with weak tissues which have frequent breakage (Emeritus and Wilkens, 142). There are other nonchemical forms of height control which can be done on a day to day basis. Cultivar selection may be one of the easiest ways to get the desired height. Some varieties are just genetically tall. Another way to increase height is to increase temperature. Chemical processes occur at a faster rate when temperatures increase which influence growth. The light that reaches the plant can be directly related to spacing. When the cuttings are spaced closer together, there is less light. Another factor is the quality of light that they receive. The ratio between different types of light can also affect height. A high red-to-far-red ratio will reduce internode length. Other cultural factors such as pinching will impact

length of stems by lengthening the vegetative growth before the plants are moved to short days for flower initiation. A delayed pinch will increase height more than a normally timed pinch. Container size can impact plant height by restricting or encouraging roots (Emeritus and Wilkens, 152).

Nutrients can significantly affect plant vigor. Excess fertilizers encourage growth, especially ammonium nitrogen and phosphorus. But, high fertilization can make the electrical conductivity (EC) too high which can reduce growth. High salinity levels can restrict water uptake. Water stress is an important limiting factor for growth and routine wilting should be avoided. There are known effects on mums with brushing or shaking the plants mechanically which can reduce growth. Another cultural way to influence height is called DIF. DIF is the difference between the day temperatures and the night temperatures. When the difference between the day and night temperatures are greater, there is stem elongation and it is referred to as positive DIF (Emeritus and Wilkens, 153). Early morning, before and after dawn, for 2 to 4 hours are when most of the stem elongation occurs and when temperatures are too low, negative DIF occurs and height is reduced. Alternative names are DROP and DIP. Negative DIF can be overcome by high temperatures during the rest of the day (Emeritus and Wilkens, 154).

Plant height can be tracked graphically by using a certain technique. Plot the points: minimum desired final plant height + pot height, maximum desired final plant height + pot height, ½ min plant height + pot height, ½ max plant height + pot height, and pot height or initial height of the cutting or seedling on a piece of paper. Connect the minimum final plant height and the maximum final plant height lines to the starting pot height. This helps the grower maintain the desired crop height as the plant continues to grow. Continue to record the plant height as the

weeks go on and if the temperatures go above or below normal use control measures to adjust height (Emeritus and Wilkens, 155).

More plant growth regulators (PGRs) are required during winter to compensate for when temperatures and light levels are lower and growth is slower. The mode of application can affect efficacy of PGRs. Drenches are more effective because they are more uniform than a foliar spray. There is better coverage and also the chemicals in the drenches remain active longer in the media because they don't dry out as quickly. However, drenches are more expensive because a higher quantity of the product is needed for the same treatment. Sprayer sizing can affect efficiency because a smaller droplet will infiltrate the foliage of the plant better. When lower concentrations are used and applied several times they are usually more effective than a one-time application of a higher concentration and will reduce phytotoxicity (Emeritus and Wilkens, 158).

Gibberellins as Plant Growth Regulators

Gibberellic acids are plant regulators used for cell division and cell elongation. When applied they can often make the plant mature more quickly and make seed germinate more quickly. There are two common products of gibberellins; gibberellic acid and potassium gibberellate (Anonymous, EPA R.E.D. FACTS).

Gibberellin have other positive effects, for example it can replace some cold treatments, for example in azaleas with foliar sprays of 1000 ppm weekly. Where every spray application can replace 1 week of cold treatments. GA can also be used on cyclamen to increase stem elongation if 10 to 25ppm is applied 8 weeks before flowering (Emeritus and Wilkens, 157).

Factors Affecting Chemical Application Efficacy

When applying exogenous plant growth regulators there are a few things to consider in order to have the most effective application. If the light intensity is too high or the wind speeds are too

fast, the foliar sprays can dry out too quickly and won't be absorbed properly. Conversely, high humidity causes the opposite effect where the product takes too long to dry and too much of the product gets absorbed. Substrate ingredients can affect the efficiency of the chemicals by tying them up. pH of the soil can also tie up nutrients. Stage of growth can affect how easily the chemicals are taken up. Irrigation or rain just after the PGR has been applied can wash away the chemicals and make them less effective. Pay attention to the expiration date of the chemicals, as they can become less active over time. Uniformity is also needed for an effective application and can be affected by the sprayer calibration, waxy cuticles, and substrate uniformity (Hoover).

Research Related to Gibberellins and Cytokinins

A study was conducted on woody plants such as *Spiraea canescens, Lonicera maakii***,** and *Cornus alba*, with silver thiosulfate (STS) by itself and also in combination with GA. They tested shoot elongation of the dormant stems. GA_3 was applied at 50 mg per liter for 24 hours and also GA and STS was used in combination for the same amount of time. When the amount of time was increased, the time to bud break was shorter. The combination trial was most effective. The treatment with GA_3 and STS doubled stem elongation in comparison to the STS by itself (Bahget and Read).

Exogenous PGRs GA_3, GA_4+$GA_{7,}$ GA_5 and GA_9 were used with the cytokinin benzylamine (BA) during non-inducive long days to improve flowering and inflorescence development of mums. The most effective treatment was GA_5 and BA. The second most effective was GA_3 and BA. When the treatments were used by themselves they had good results with flowering as well. The most effective were GA_3 and GA_5 when used in higher concentrations. Inflorescence development was limited when concentrations of GA were lower (Pharis).

Growth retardant chlorphonium chloride (Cycocel) and daminozide (B-Nine) were used to delay the time to anthesis of pot mums. Then one dose of 20 or 40 μg gibberellic acid (GA) was used and the mums completely overcame the effects of the growth retardants in regards to both stem length and flowering. Other PGRs did not have the same positive reversal effects, such as piproctanyl bromide. Leaf number was never affected by the treatments. This study reinforced the previous knowledge that gibberellins have an important part in influencing stem elongation and the time it takes to flower in mums. This is because they encourage flower bud development (FBD) and increase time to anthesis by drawing in assimilates to those parts of the plant (Menhenett, 305-18).

Gibberellins were used to ensure vegetative growth and flowering of Ceylon rock primrose. The experiment consisted of using 25ml GA_3 for 4 weeks. The treatment was broken down so that 0, 2.5, 5, 10 mg of active ingredient were sprayed onto the leaves 2 weeks after planting and again 2 weeks later and then again 6 weeks later after transplanting. The results showed that flowering was faster with more inflorescences with 200 ppm GA_3 as compared to the other treatments of 0, 50 and 100 pm. While 200 ppm1 had the best results, the other treatments were also effective in increasing peduncle, petiole and plant length and were not significantly different from the 200 ppm treatment.Overall, these effects gave the plant better form. The results showed that GA_3 had beneficial impacts on both vegetative and reproductive growth. GA_{4+7} also had positive effects on floral initiation and development (Sumanasiria, 29-32).

An experiment used GA_3 on potted mums to test for best timing of foliar sprays to improve clubby stems. The study found that GA_3 increased the final plant height. When the product was applied at weeks 1, 2 or 3 it increased the plant height but when it was applied at week 4 or 5 it had minimal effects (Holcomb, Tukey, and Rose, 312).

Giberellins A_1 through A_9 were used on 5 different plants to test for stem elongation and flower development. All of the different chemical forms had varying effects on the formation of the flowers and the different plants had different sensitivities. GA_3 was most effective. $GA_{1, 4}$ and $_7$ were the next effective products, flowed by GA 5 and 9. Induction of flowers only effective with GA_7. Overall $GA_{3, 4}$, and $_7$ were the most effective in all species (Michniewicz and Anton, 549-63).

The ratio of cytokinins and auxin are correlated to apical dominance. Cytokinins can somewhat undo the effects of auxin on lateral buds. When cytokinin is applied directly to the stems of *Ipomoea nil* there was positive effects on bud outgrowth (Cline, Wesse and Iwamura)

As it says on the label of GibGro 4LS (4% Liquid Gibberellic Acid), GA can be used on many cut flowers, including pompon chrysanthemums in all states except California. It can be used to elongate the peduncles by applying a single spray 4-5 weeks after the start of short days. Apply using a spray solution at 25-60 ppm directly on the flower buds. If incorrectly timed usage or used at too high of a concentration it will cause long, spindly and weak stems (Anonymous, GibGro 4LS).

Materials and Methods

Variety

The cut mum variety was ‘Discovery’. The flower is a green spray button. It prefers pH of 5.5-6.5 and light of 4,000 foot candles. Temperature should be at 55 degrees C. Irrigation should be moderate. Fertilization should be 250 ppm of constant N and K. It is a cold tolerant variety (Anonymous, GroLink).

Day Length

The mums were grown at Califonia Polytechnic State University’s Environmental Horticultural Unit in House 9: Enterprise House. The plants were kept on the bench closest to the cooling pads. The plants kept in long days were on the east side of House 9. The long days were made possible with TCP # 35026/27, 26W, 2700K bulbs (Figure 1 and 2). When the plants were transitioned to short day they were moved to the west side of House 9 and were black clothed at 5pm every night and removed it at 8am every morning.

Figure 1. Lighting used for long days

Figure 2. Light bulb used for long days

Planting

Rooted cuttings were delivered from Gro Link, a production greenhouse in Oxnard, and were planted soon after the delivery date. Both trials of rooted cuttings spend a few days in the flower cooler. The mums were planted in black plastic crates with the dimensions of 23 centimeters x 15.5 cm x 9.5 centimeters. The spacing was 20 cuttings per crate, which was 17.825 centimeters squared per plant (Figure 3, 4 and 5). There were two trials and the medium mix for the Trial 1 was 7 cubic feet sphagnum peat moss, 7 cubic feet perlite and 7 cubic feet fir bark with 21 ounce Dolomite and 17 ounce treble superphosphate. Osomocote 14-14-14 was used as a topdess after steaming. The medium for the Trial 2 was a modified peat-lite mix, which is composed of 10 cubic feet peat moss, 10 cubic feet perlite, 12 ounce treble superphosphate (0-45-0), 18 ounce potassium nitrate (13-0-44), 59 ounce dolomite lime and 1 ounce Micromax Plus. Topdressing of 14-14-14 was used after it was steamed. All media was pasteurized by steam before the cuttings were transplanted. The greenhouse temperature was set at 65 degrees F at night and 72 degrees F during the day. Irrigation was done by a hand on an as-needed basis.

Irrigation water contained 200 ppm nitrogen and 200 ppm potassium derived from potassium nitrate and calcium nitrate. Peters Professional 20-10-20 fertilizer at 1 ounce to 3 gallons of water was used to water in planted cuttings.

Figure 3. Cuttings being planted in crates

Figure 4. Rooted cuttings after they were planted

Figure 5. Bench next to cooling pads with black cloth

Experimental Design

The crates were lined up next to each other in one row (Figure 6). The replicate for 0 long days was at the end of the row. This was followed by the replicate for 6 long days with 50ppm and 100ppm and then 6 long days with 0 and 50+50. Next was 10 long days with 50ppm and 100ppm and then 10 long days with 0 and 50+50. In the middle was 13 long days with 50ppm and 100ppm and then 13 long days with 0 and 50+50. This followed with 17 long days with 50ppm and 100ppm and then 17 long days with 0 and 50+50. Finally 20 long days with 0ppm and 100ppm was at the end of the row closest to the aisle (Figure 7,8 and 9).

Figure 6. Rooted cuttings on east side of greenhouse, where long days occurred.

0 LD	6LD	10 LD	13 LD	17 LD	20 LD

West side East side

Figure 7. Experimental Design of Treatments

Figure 8. Experimental design of fully grown mums on west side of greenhouse where short days occurred, horizontal view

Figure 9. Experimental design of fully grown mums on west side of greenhouse where short days occurred, vertical view

Harvest

The cut flowers were selectively harvested when the oldest bud in the inflorescence was fully open and starting to turn a lighter green. The flowers were cut at the soil level.

Data Collection

Height (cm)

Measurements of height were from the soil level of the stem to the top of the flower inflorescence. The measurements were recorded in centimeters.

Flower Rating

The flower sprays were given a numerical rating of 1 through 5 (Figure 10).

Figure 10. Flower Inflorescence Ratings

1	Unacceptable, clubby, 0centimeters peduncle, minimal flowers, very small head or crown buds
2	Unacceptable, clubby, 0.1-0.5 centimeters peduncle, minimal flowers, small head
3	Unacceptable, semi-clubby, 0.6-2.0 centimeters peduncle, adequate flowers, medium head
4	Acceptable, not clubby, 2.1-3.0 centimeters peduncle, adequate flowers, semi-large head
5	Acceptable, not clubby, 3.1- centimeters peduncle, maximum flowers, large head

Trial 1 ProGibb 4% Treatments

Figure 11. Method of spraying product solution onto plants

0 Long Days 1-time application 100ppm and 0ppm

20 cuttings were planted on February 24 in one crate. 10 cuttings were swished in 100 ppm ProGibb 4% solution for 3 seconds. The other 10 cuttings were swished in tap water without added fertilizer for 3 seconds. The treatment went under short days on February 24. The treatment was disbudded to a spray form on April 11. The 100ppm flowers were harvested on May 1. The 0ppm flowers were harvested on May 1.

6 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on February 22 in one crate under long days. When the cuttings became turgid on February 28, 50ppm ProGibb 4% solution was applied to 10 cuttings and 100ppm ProGibb 4% was applied to the other 10 cuttings (Figure 11). The treatment was put

under short days on February 28. The treatment was disbudded to a spray form on April 15. The 50ppm flowers were harvested on May 1. The 100ppm flowers were harvested on May 1.

6 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on February 22 in one crate under long days. When the cuttings became turgid on February 28 the first application of 50ppm ProGibb 4% solution was applied to 10 cuttings and the other 10 cuttings received no application. 4 days later on March 4 the second application of 50ppm ProGibb 4% solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on February 28. The treatment was disbudded to a spray form on April 28. The split rate 50ppm flowers were harvested on May 1, May 3 and May 7. The no-application flowers were harvested on May 1.

10 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on February 22 in one crate under long days. On March 4, 50ppm ProGibb 4% solution was applied to 10 cuttings and 100ppm ProGibb 4% was applied to the other 10 cuttings. The treatment was put under short days on March 4. The treatment was disbudded to a spray form on April 28. The 50ppm flowers were harvested on May 1 and May 3. The 100ppm flowers were harvested on May 1.

10 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on February 22 in one crate under long days. On March 1 the first application of 50ppm ProGibb 4% solution was applied to 10 cuttings and the other 10 cuttings received no application. 3 days later, March 4, the second application of 50ppm ProGibb 4% solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on March 4. The treatment was disbudded to a spray form on

April 28. The split rate 50ppm flowers were harvested on May 1 and May 3. The no-application flowers were harvested on May 3 and May 5.

13 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on February 22 in one crate under long days. On March 7, 50ppm ProGibb 4% solution was applied to 10 cuttings and 100ppm ProGibb 4% was applied to the other 10 cuttings. The treatment was put under short days on March 7. The treatment was disbudded to a spray form on April 28. The 50ppm flowers were harvested on May 3, May 5 and May 9. The 100ppm flowers were harvested on May 3 and May 9.

13 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on February 22 in one crate under long days. On March 4 the first application of 50ppm ProGibb 4% solution was applied to 10 cuttings and the other 10 cuttings received no application. 3 days later, March 7, the second application of 50ppm ProGibb 4% solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on March 7. The treatment was disbudded to a spray form on April 28. The split rate 50ppm flowers were harvested on May 3. The no-application flowers were harvested on May 3 and May 5.

17 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on February 22 in one crate under long days. On March 11, 50ppm ProGibb 4% solution was applied to 10 cuttings and 100ppm ProGibb 4% was applied to the other 10 cuttings. The treatment was put under short days on March 11. The treatment was disbudded to a spray form on April 28. The 50ppm flowers were harvested on May 5, May 7 and May 9. The 100ppm flowers were harvested on May 5 and May 7.

17 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on February 22 in one crate under long days. On March 7 the first application of 50ppm ProGibb 4% solution was applied to 10 cuttings and the other 10 cuttings received no application. 4 days later, March 11, the second application of 50ppm ProGibb 4% solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on March 11. The treatment was disbudded to a spray form on April 28. The split rate 50ppm flowers were harvested on May 5. The no-application flowers were harvested on May 5 and May 7.

20 Long Days 1-time application 100ppm and no-application

20 cuttings were planted on February 22 in one crate under long days. On March 14, 50ppm ProGibb 4% solution was applied to 10 cuttings and 100ppm ProGibb 4% was applied to the other 10 cuttings. The treatment was put under short days on March 14. The treatment was disbudded to a spray form on April 28. The 100ppm flowers were harvested on May 7, May 9, May 11 and May 17. The no-application flowers were harvested on May 9, May 11 and May 17.

Trial 2 Fascination Treatments

0 Long Days 1-time application 100ppm and 0ppm

20 cuttings were planted on March 28 in one crate. 10 cuttings were swished in 100 ppm Fascination solution for 3 seconds. The other 10 cuttings were swished in tap water for 3 seconds. The treatment went under short days on March 28. The 100ppm flowers were disbudded to a spray form on May 3. The 0ppm flowers were disbudded to a spray form on May 3. The flowers were not harvested.

3 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on March 28 in one crate under long days. When the cuttings became turgid on April 3, 50ppm Fascination solution was applied to 10 cuttings and 100ppm Fascination was applied to the other 10 cuttings. The treatment was put under short days on April 3. The 50ppm flowers were disbudded to a spray form on May 7. The 100ppm flowers were disbudded to a spray form on May 7. The flowers were not harvested.

3 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on March 28 in one crate under long days. When the cuttings became turgid on April 3 the first application of 50ppm Fascination solution was applied to 10 cuttings and the other 10 cuttings received no application. 5 days later on April 8 the second application of 50ppm Fascination solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on April 8. The split rate 50ppm flowers were disbudded into spray form on May 7. The no-application flowers were disbudded into spray form on May 5. The flowers were not harvested.

10 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on March 28 in one crate under long days. On April 8, 50ppm Fascination solution was applied to 10 cuttings and 100ppm Fascination was applied to the other 10 cuttings. The treatment was put under short days on April 8. The 50ppm flowers were disbudded to a spray form on May 7. The 100ppm flowers were disbudded to a spray form on May 7. The flowers were not harvested.

10 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on March 28 in one crate under long days. On April 4 the first application of 50ppm Fascination solution was applied to 10 cuttings and the other 10 cuttings

received no application. 4 days later, April 8, the second application of 50ppm Fascination solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on April 8. The split rate 50ppm flowers were disbudded into spray form on May 7. The no-application flowers were disbudded into spray form on May 5. The flowers were not harvested.

13 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on March 28 in one crate under long days. On April 11, 50ppm Fascination solution was applied to 10 cuttings and 100ppm Fascination was applied to the other 10 cuttings. The treatment was put under short days on April 11. The 50ppm flowers were disbudded to a spray form on May 7. The 100ppm flowers were disbudded to a spray form on May 7. The flowers were not harvested.

13 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on March 28 in one crate under long days. On April 8 the first application of 50ppm Fascination solution was applied to 10 cuttings and the other 10 cuttings received no application. 3 days later, April 11, the second application of 50ppm Fascination solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on April 11. The split rate 50ppm flowers were disbudded into spray form on May 7. The no-application flowers were disbudded into spray form on May 5. The flowers were not harvested.

17 Long Days 1-time application 50ppm and 100ppm

20 cuttings were planted on March 28 in one crate under long days. On April 15, 50ppm Fascination solution was applied to 10 cuttings and 100ppm Fascination was applied to the other 10 cuttings. The treatment was put under short days on April 15. The 50ppm flowers were

disbudded to a spray form on May 7. The 100ppm flowers were disbudded to a spray form on May 7. The flowers were not harvested.

17 Long Days Split Rate Application 50ppm and no-application

20 cuttings were planted on March 28 in one crate under long days. On April 11 the first application of 50ppm Fascination solution was applied to 10 cuttings and the other 10 cuttings received no application. 4 days later, April 15, the second application of 50ppm Fascination solution was made to the 10 cuttings and the other 10 cuttings received no application. The treatment was put under short days on April 15. The split rate 50ppm flowers were disbudded into spray form on May 7. The no-application flowers were disbudded into spray form on May 5. The flowers were not harvested.

20 Long Days 1-time application 100ppm and no-application

20 cuttings were planted on March 28 in one crate under long days. On April 18, 50ppm Fascination solution was applied to 10 cuttings and 100ppm Fascination solution was applied to the other 10 cuttings. The treatment was put under short days on April 18. The 100ppm flowers were disbudded to a spray form on May 5. The 0ppm flowers were disbudded to a spray form on May 5. The flowers were not harvested.

Results and Discussion

Trial 1 Results

After the data was collected for Trial 1, analysis was done using the SAS System with GLM Procedure. Then Duncan grouping was done (Appendix).

TriAl 2 Observations

Observations were made on May 22, 2014. Trial 2 experiments were terminated on May 22 due to the majority of the flowers being unmarketable (Table 1). None of the flowers were harvested.

Table 1. Trial 2 Flower Ratings

Treatment	Flower Rating
0 LD, 100 ppm	5
0 LD, 0 ppm	5
3 LD, 50 ppm	5
3 LD, 100 ppm	0
3 LD, 50+50 ppm	0
3LD, 0 ppm	0
10 LD, 50 ppm	4
10 LD, 100 ppm	5
10 LD, 50+50 ppm	0
10LD, 0 ppm	5
13 LD, 50 ppm	3
13 LD, 100 ppm	4
13 LD, 50+50 ppm	5
13 LD, 0 ppm	5
17 LD, 50 ppm	3
17 LD, 100 ppm	3
17 LD, 50+50 ppm	4
17 LD, 0 ppm	5
20 LD, 100 ppm	5
20 LD, 0 ppm	4

0 Long Days 1-time application 100ppm and 0ppm

The 100ppm flowers had an average of a 5 flower rating. The height was average to the entire Fascination trial.

The 0ppm flowers had their 1st flower in bloom on May 22. The average flower rating was 5. The flowers were more one than the 100ppm flowers at this time. The height was average and they had long peduncles.

3 Long Days 1-time application 50ppm and 100ppm

The 50ppm flowers were very tall. The flowers were all crowns, except for one flower which was a 5 rating (Figure 12). The flowers were more immature than the 100ppm.

Figure 12. Crown bud

The 100ppm flowers were all crowns with 0 ratings and were not as tall as the 50ppm flowers.

3 Long Days Split Rate Application 50ppm and no-application

The split rate application flowers were all crowns with 0 ratings and were about as tall as the 0 long days treatment.

The 0ppm flowers were more mature than the split rate application flowers. All of the flowers were crowns, but they were more acceptable looking than the split rate flowers. The height was taller than the split rate flowers.

10 Long Days 1-time application 50ppm and 100ppm

The 50ppm flowers had an average of a 4 flower rating. The height was taller than the 100ppm flowers and were less mature.

The 100ppm flowers had a 5 flower rating.

10 Long Days Split Rate Application 50ppm and no-application

The split rate application flowers were all crowns. The crowns were more acceptable than the 3 long days with 100ppm flowers.

The 0ppm flowers all had a 5 flower rating and were more mature than the split rate flowers. They were also taller.

13 Long Days 1-time application 50ppm and 100ppm

The 50ppm flowers had a 3 flower rating. The leaves were short, chlorotic and wrinkly (Figure 13).

Figure 13. Wrinkly leaves with sunken lesions and cupped under

The 100ppm flowers had 4 flower ratings and were more mature than the 50ppm flowers. The leaves were wrinkly.

13 Long Days Split Rate Application 50ppm and no-application

The split rate application flowers had a 5 flower rating. The leaves were wrinkly.

The 0ppm flowers were taller than the split rate flowers and had a 5 flower rating. The leaves were wrinkly.

17 Long Days 1-time application 50ppm and 100ppm

The 50ppm flowers had a 3 flower rating. The flower form was slightly abnormal looking and the leaves were wrinkly.

The 100ppm flowers had a 3 flower rating and some of them were abnormal looking. The leaves were wrinkly.

17 Long Days Split Rate Application 50ppm and no-application

The split rate application flowers had a 4 flower rating and were wrinkly.

The 0ppm flowers were tall. The flowers were more mature than the split rate application flowers. The flower rating was a 5. The leaves were wrinkly.

20 Long Days 1-time application 100ppm and no-application

The 100ppm flowers had a 5 rating and were wrinkly.

The 0ppm flowers had a 4 rating and were shorter than the 100ppm flowers. The leaves were wrinkly. There were problems with this treatment drying out, as it was on the end of the row (Figure 14).

Figure 14. Under watered plant with wilted leaves

Conclusion

Trial 1: ProGibb 4%

The objective of the experiment was to shorten the schedule of cut mums without affecting the quality. This was made possible by reducing the long days and supplementing the flowers with ProGibb 4% to elongate the stems. The 0 long days treatments were both harvested on May 1st. This was 36 days from the planting date, which is about 5.14 weeks. The average flower rating was a 4 for both the 0 ppm and 100 ppm. The average height for 0ppm was 12.66 centimeters and the average for 100 ppm was 13.51centimeters. The 20 long days treatment with no application had its last stem harvested on May 17. This was 52 days from planting and about 7.43 weeks. The average flower rating was 4 for 0 ppm and a mix between 3's, 4's, and 5's for

100ppm. The average height for 0 ppm was 20.02centimeters and the average for 100 ppm was 19.29centimeters. The difference between the plantings was 26 days which was 2.29 weeks.

The treatment for 17 long days shows significance in Figure 17. 100ppm at 17 long days has a taller stem than with the 0ppm treatment. This shows that the schedule could be made four days shorter. The flower form also remained adequate. These results are most likely due to the plants actively rooting at 17 days and are therefore responsive to the treatment.

Trial 2: Fascination

The results of the mums sprayed with the Fascination treatment were unpredictable. The majority were crown buds and were unmarketable. The experiment was terminated due to these factors. This product is not recommended to be used on cut mums, based on the experiment. Cultivar may have played a role in the results as well.

Recommendations

There were many problems which impacted the effectiveness of this experiment. The results were often inconclusive because of the lack of replicates. There was only one replicate done for the ProGibb 4% trial and one replicate done for the Fascination trial. There was nothing to compare the results to and this made it difficult to analyze the statistical results and even the observations. There was also no randomized complete block design for the replicates. Therefore there could have been environmental issues which could have affected the results. For example, it was difficult to know whether the 20 long days with 0ppm had poorer flower forms because they were under watered, because they were on the end, or because of their treatment. This is where the replicates with a randomized design would have been helpful. There were also problems with the ProGibb 4% statistical results. First of all there were outliers in height and flower form which could have drastically affected the means. Secondly, it would have been

better to harvest all the cuttings of one treatment at once instead of harvesting each flower on different days. Lastly, the 0 long ays and the 20 long days treatments did not have 50ppm or split rate applications like the other long day treatments did, which made it difficult to make comparisons. The last big problem for the ProGibb 4% trial was that there were small infestations of aphids of the flowers (Figure 15) and some watering infrequency. This may have affected the flower form ratings and height.

Figure 15. Aphid infestation on flower

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Appendix

Data

SAS System with GLM Procedure

Trial 1: 50ppm's removed: ppm

Dependent Variable: Harvest: ppm not significant

Dependent Variable: Rating: ppm not significant

Trial 1: 0 Long Days and 21 Long Days removed: ppm

Dependent Variable: Harvest: ppm significant for 10 long days

Table 2. Duncan's Multiple Range Test for Harvest, 10 long days, Alpha 0.05

ppm	Duncan Grouping
0	A
50+50	B
50	C
100	C

Dependent Variable: Height: ppm not significant

Dependent Variable: Rating: ppm significant for 10 long days

Table 3. Duncan's Multiple Range Test for Rating, 10 long days, Alpha 0.05

ppm	Duncan Grouping
100	A
50+50	A
0	B
50	B

Trial 1: 0 Long Days and 21 Long Days removed: Days * ppm

Dependent Variable: Harvest: Interaction between days and ppm

Table 4. Duncan's Multiple Range Test for Harvest, Alpha 0.05

Long Days	Duncan Grouping
17	A
14	B
10	C
6	D

Table 5. Duncan's Multiple Range Test for Harvest, Alpha 0.05

ppm	Duncan Grouping
50	A
0	A
50+50	B
100	B

Dependent Variable: Height: No interaction between days and ppm

Dependent Variable: Rating: Interaction between days and ppm

Table 6. Duncan's Multiple Range Test for Rating, Alpha 0.05

Long Days	Duncan Grouping
6	A
10	B
14	B
17	C

Table 7. Duncan's Multiple Range Test for Rating, Alpha 0.05

ppm	Duncan Grouping
100	A
50+50	A
0	A
50	B

Trial 1: 50 ppm removed: Days * ppm

Dependent Variable: Harvest

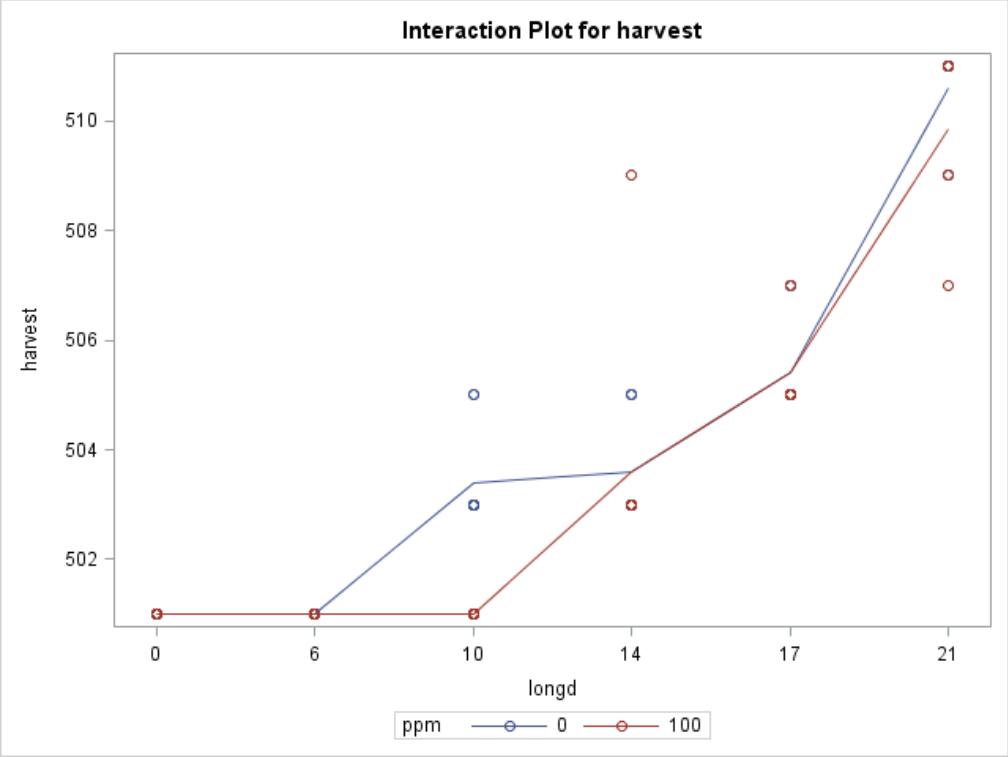

Figure 16. Dependent Variance Harvest. Interaction between long days and ppm

Table 8. Duncan's Multiple Range Test for Harvest, Alpha 0.05

Long Days	Duncan Grouping
21	A
17	B
14	C
10	D
0	E
6	E

Table 9. Duncan's Multiple Range Test for Harvest, Alpha 0.05

ppm	Duncan Grouping
0	A
100	B

Dependent Variable: Height

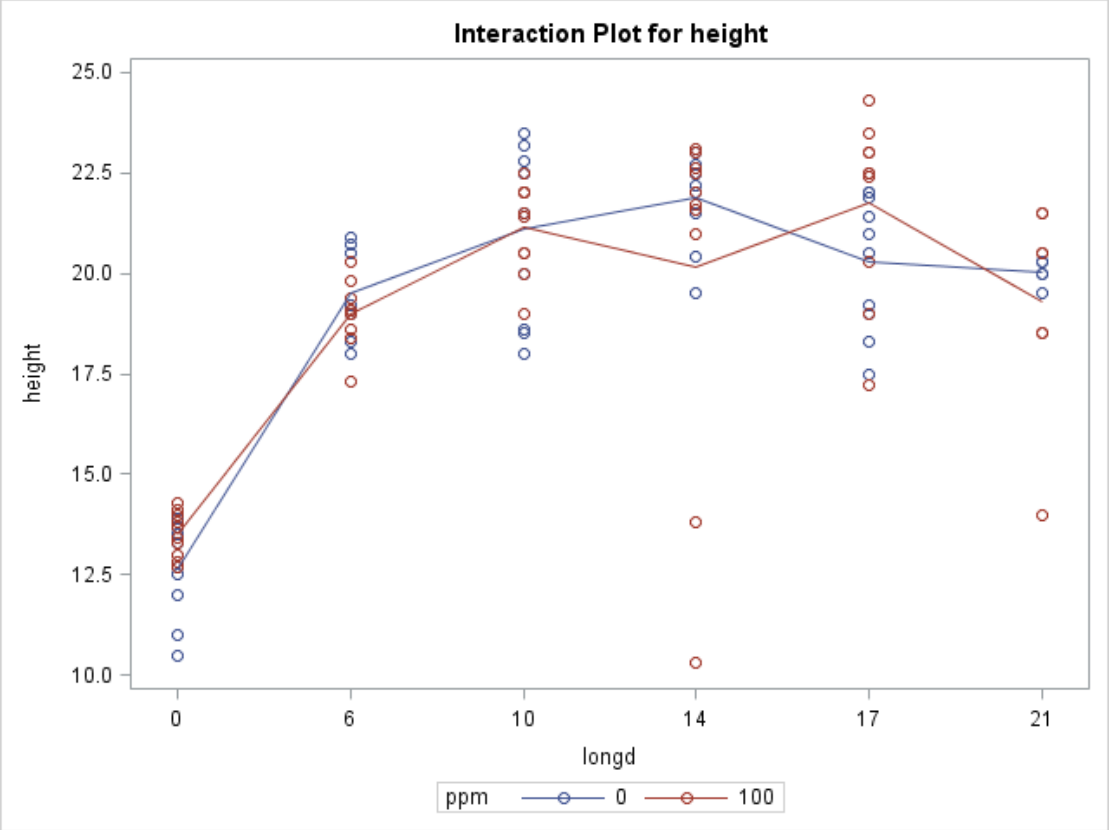

Figure 17. Dependent Variable Height. Long days significant.

Table 10. Duncan's Multiple Range Test for Height, Alpha 0.05

Long Days	Duncan Grouping
10	A
17	A
14	A
21	B
6	B
0	C

Table 11. Duncan's Multiple Range Test for Height, Alpha 0.05

ppm	Duncan Grouping
0	A
100	A

Dependent Variable: Rating

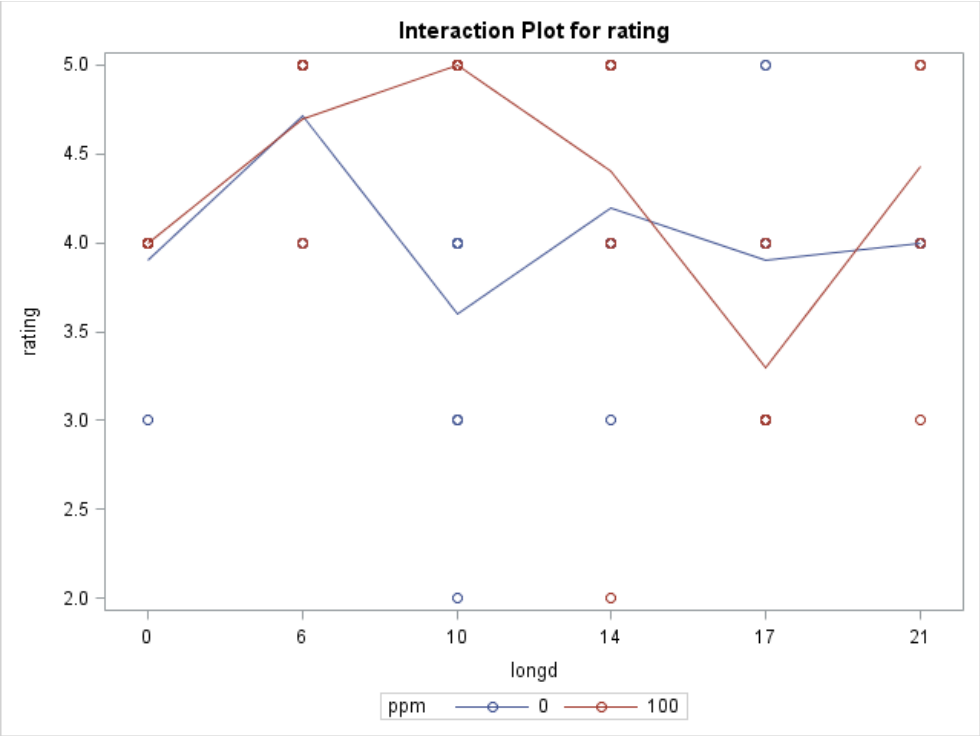

Figure 18. Dependent Variable Rating. Interaction between long days and ppm

There appears to be an interaction at 10 and 17 days for flower rating. There is a cross over interaction.

Table 12. Duncan's Multiple Range Test for Rating, Alpha 0.05

Long Days	Duncan Grouping
6	A
10	AB
14	AB
21	B
0	BC
17	C

Table 13. Duncan's Multiple Range Test for Rating, Alpha 0.05

Long Days	Duncan Grouping
100	A
0	B